

# Terrestrial Planet Finder (TPF)

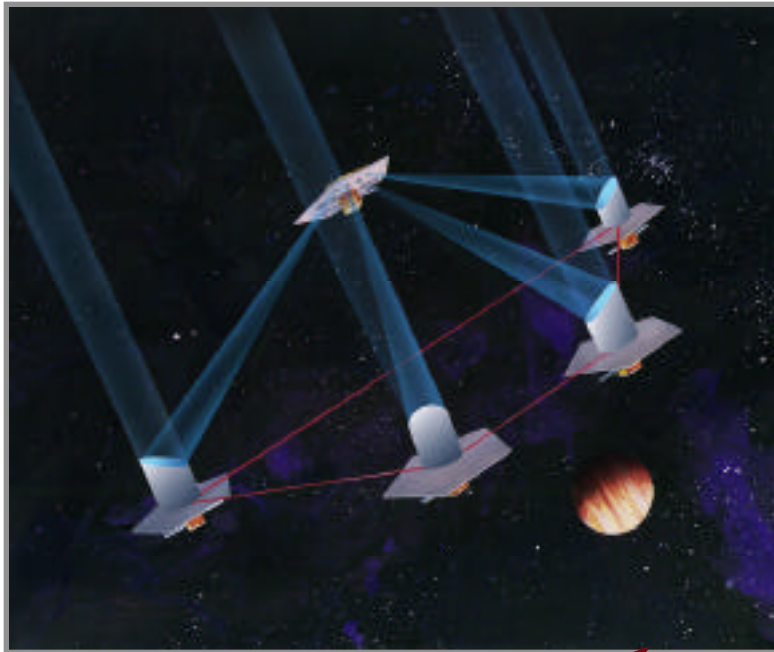
Presented by

Charles Beichman  
JPL Origins Program Scientist

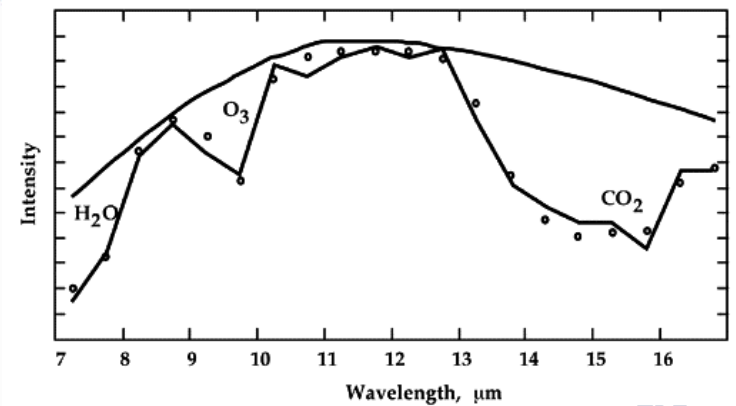
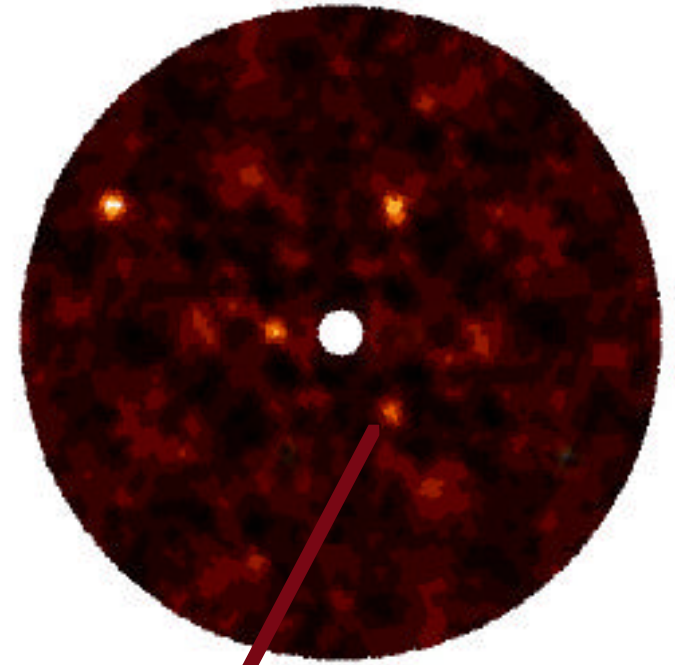
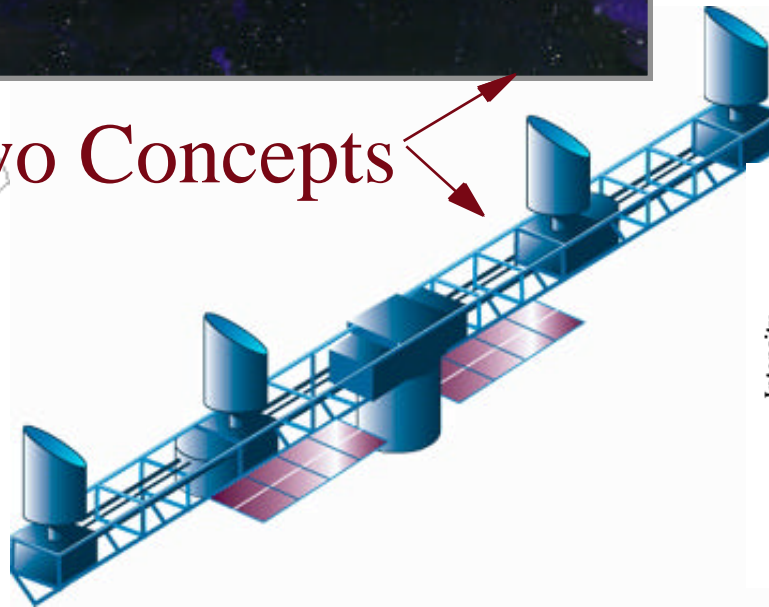
# Terrestrial Planet Finder (TPF)

*The Search for Earth-Like Planets*

Terrestrial Planet Finder

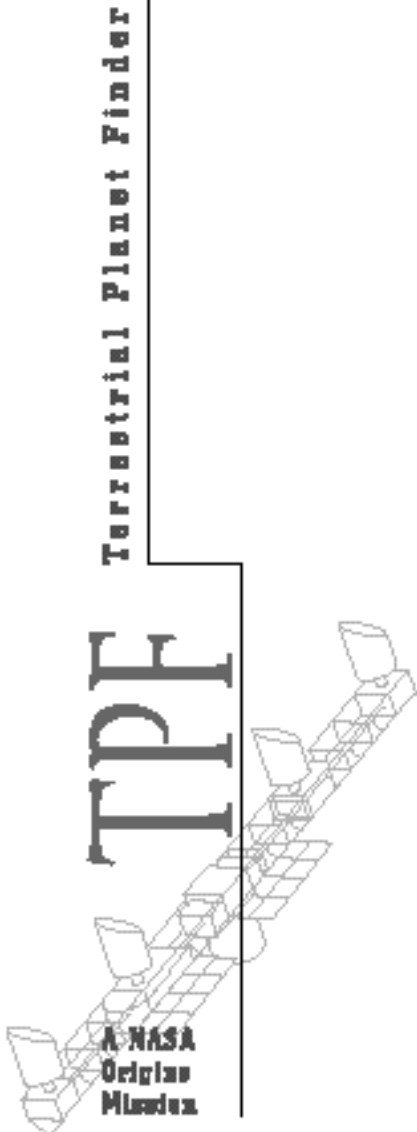


Two Concepts



# TPF Issues Examined in 1997

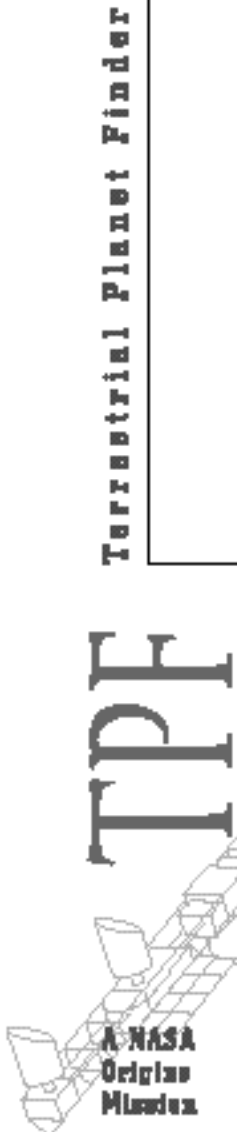
- Bio-signatures
- TPF Targets and Exo-Zodi
- System Architecture
- Technology Roadmap
- Programmatic Aspects



# TPF-SWG Guides Scientific and Technical Tradeoffs

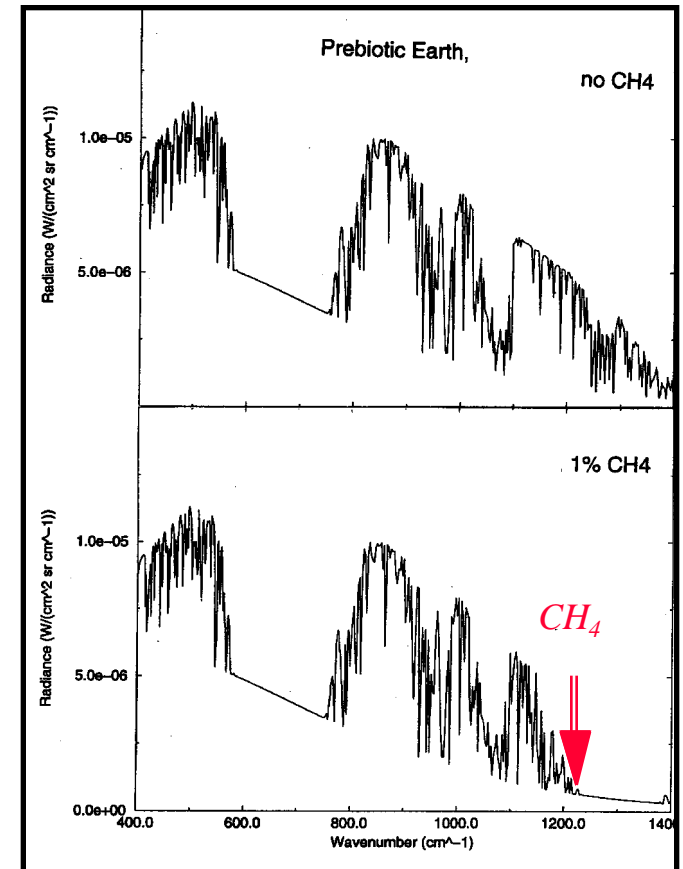
- F. Shu – Co-chair
- C. Beichman – Co-chair
- R. Angel
- D. Backman
- R. Brown
- A. Dressler
- S. Edwards
- J. Kasting
- D. Lin
- J. Lunine
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- J.-M. Mariotti
- T. Owen
- C. Schalinski
- A. Sargent
- M. Shao
- D. Wooden
- N. Woolf

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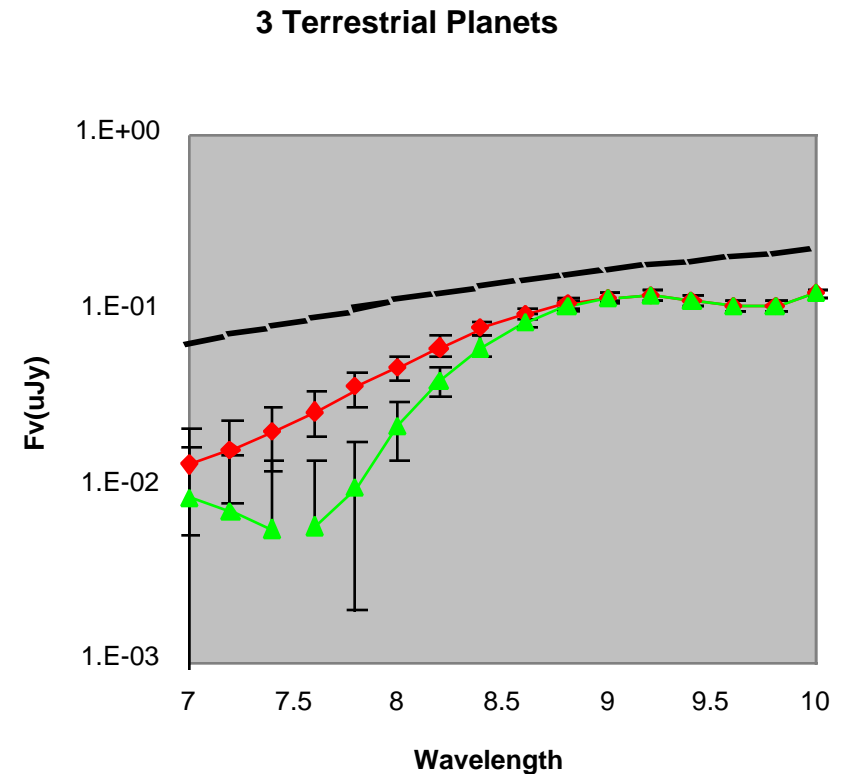
# Bio-Signatures of Life

- $O_3$  is proxy for  $O_2$  which on Earth is linked to photosynthesis
  - Oxygen abundant only within last ~ 1 billion years
- $CH_4$  produced by life in pre-photosynthetic Earth
  - Significant atmospheric abundance in absence of  $O_2$  (Kasting et al.)
- Together  $O_3$  and  $CH_4$  would provide tracers for life on Earth for almost 3.5 billion years



# TPF Detects CH<sub>4</sub> in Early Earth Analog

- Low resolution spectra can distinguish between variety of atmospheres
  - Blackbody (265 K)
  - H<sub>2</sub>O, O<sub>3</sub>, CH<sub>4</sub>
- Integrate for 10<sup>6</sup> sec for Earths at 10 pc to reveal spectral features
- Sensitivity at short wavelengths (~7 μm) drives telescope aperture and detector performance



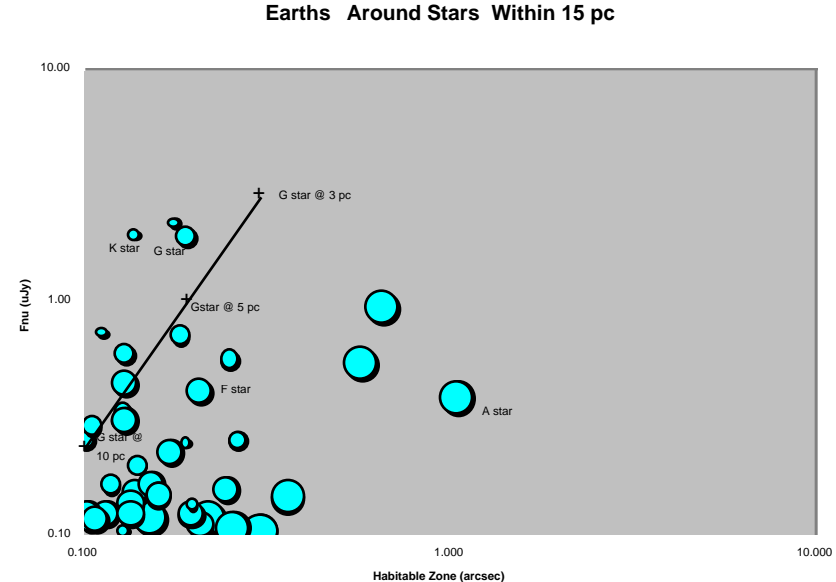
# Ames Workshop Concluded that Exo-Zodiacal Dust is a Real but.....Tractable Problem

- Asteroidal (75-90%) and cometary material is source of inner cloud
  - Likely existence of systems without asteroid belts suggests existence of systems with  $< 1$  Solar System Zodiacal cloud
  - Expected range from  $0.1$ - $10^4$  Solar System Zodiacal
- Cannot predict inner cloud from observations of outer cloud due to complex dynamical nature of the problem depending on existence and location of planets, etc. Need measurements!
- EZ is likely to be smooth (no checkerboard pattern) except for structures entrained in wakes (resonances) of planets
- Measurements with ISO, Keck-Int, LBT, SIRTf, etc. crucial to assessment of TPF targets
- EZ photon noise reduces impact of low background (5.2 AU) operation of TPF



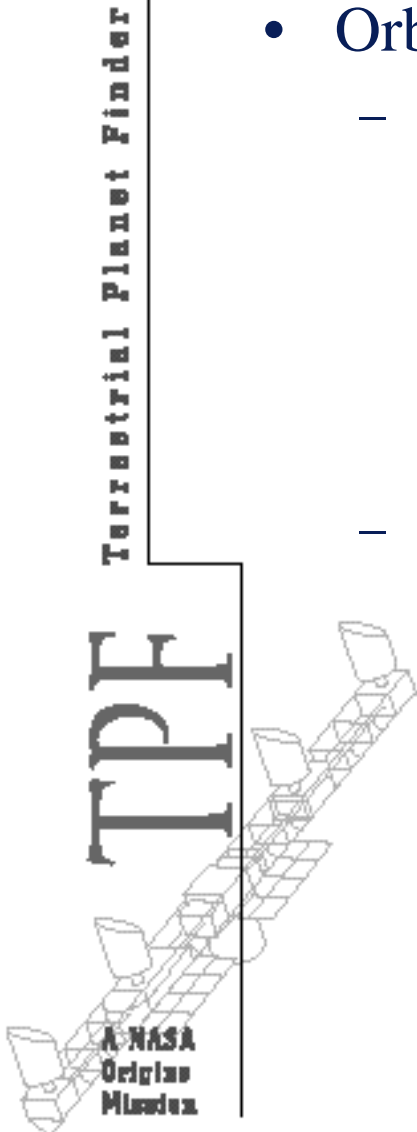
# Need Program to Identify TPF Target Stars

- TPF-SWG supports essential activities to collect data on nearby stars suitable as targets for TPF
  - Collect primary data on rotation and inclination, distance, amount of zodiacal emission, multiplicity, background stars
  - Collate data in easily accessible database



# Orbit Location Tradeoffs

- Orbit location trade shows 1 AU as a viable option
  - 1 AU
    - Exo-zodiacal emission reduces importance of low background
    - High local background requires large telescopes (4-4.5m)
    - Favorable from standpoint of mission duration, sky coverage, revisits to stars, mass and power
    - Requires (is enabled by) NGST Optics
  - 5 AU (Jupiter-assisted circular)
    - Low background allows small telescopes (1.5-2 m)
    - Requires electric propulsion
    - Mass and power problems
    - Poor sky coverage



# Studies Led to New Reference Design for TPF

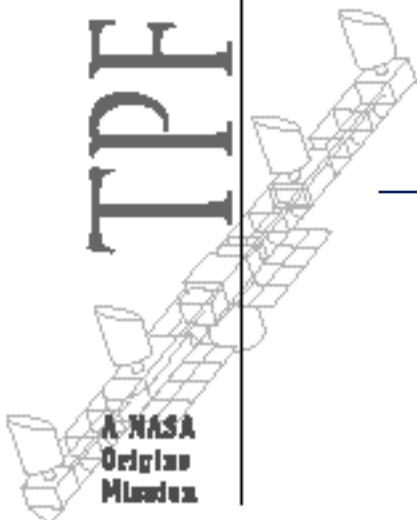
- Conducted mission and configuration studies for 1 AU and 5 AU
  - JPL Team- X
  - Ball, Lockheed-Martin, TRW
  - MIT to evaluate free-flyer vs monolith
- Adopted reference mission
  - Separated S/C
  - Nominal 75 m baseline
  - 1 AU Earth-Trailing Orbit
- Identified key areas for further study
  - Precision station-keeping of separated s/c
  - I&T of very large monolith structure



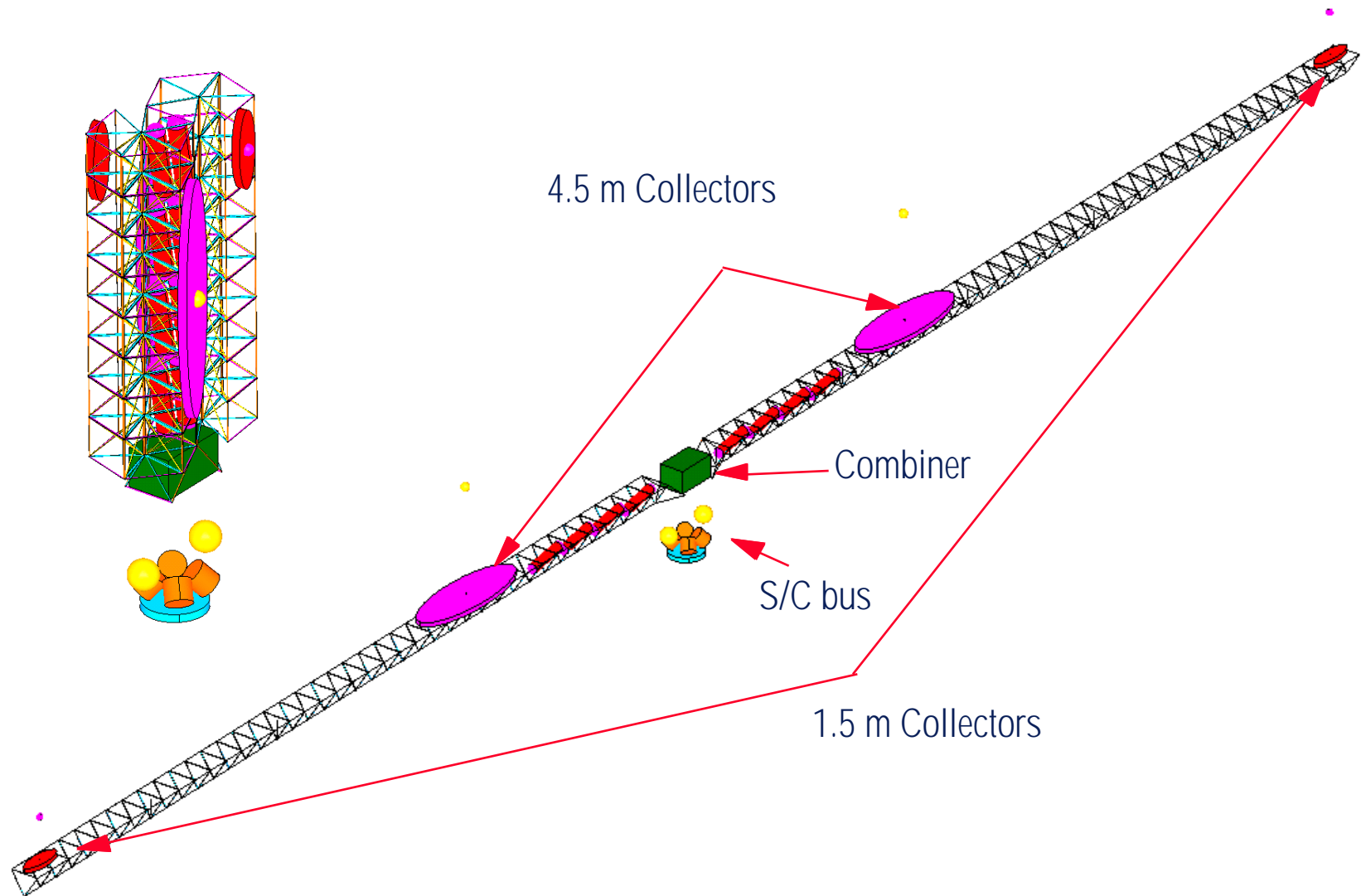
# Signal - to - Noise Ratio for 1 and 5 AU

Terrestrial Planet Finder

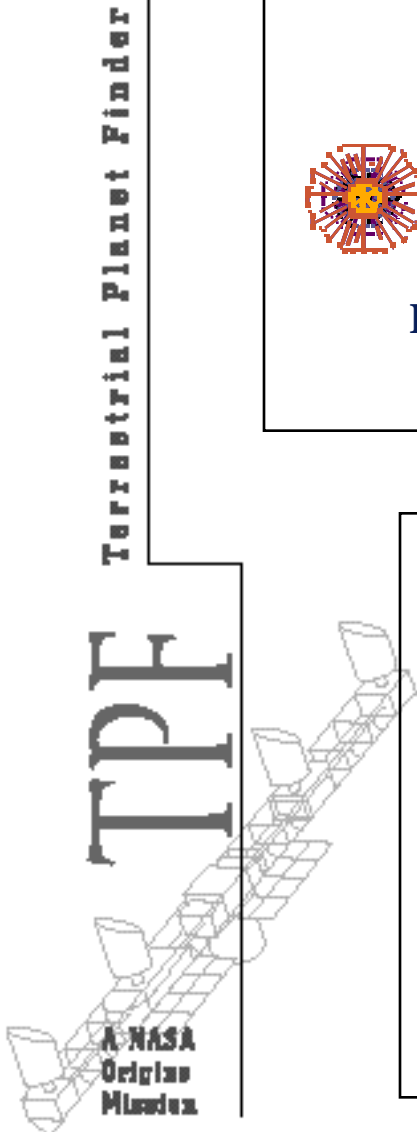
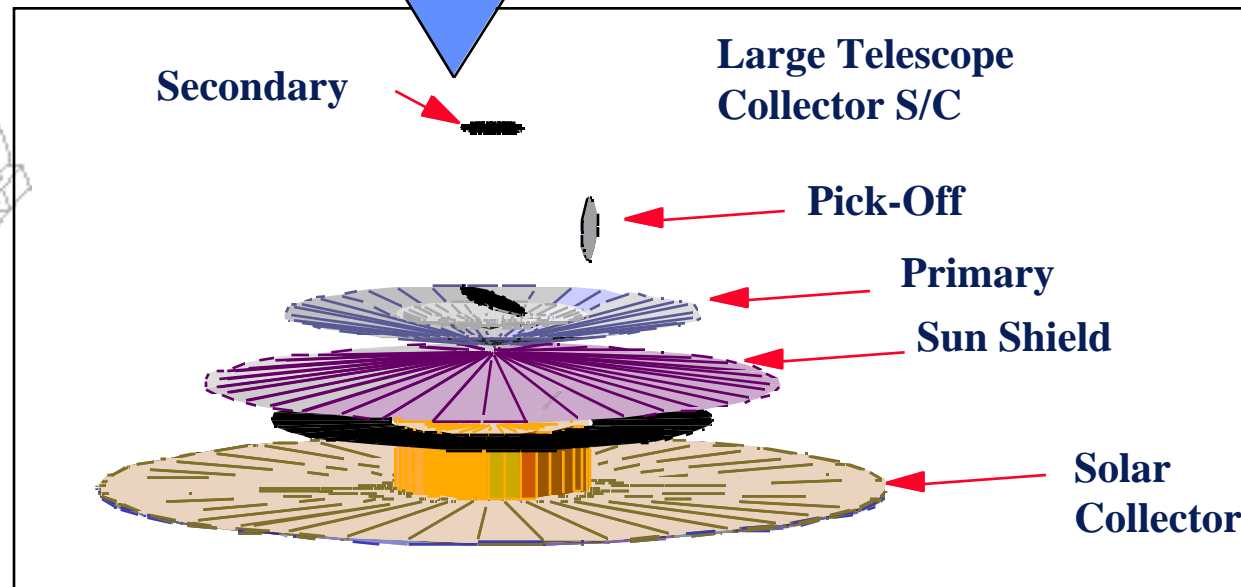
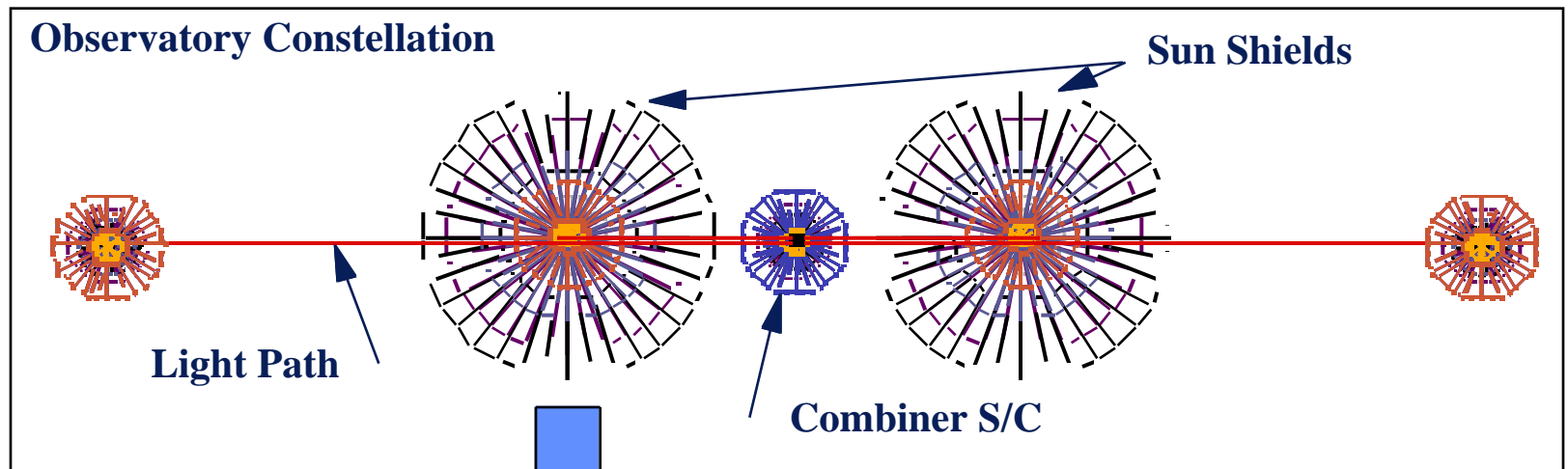
<u>Signal (e<sup>-</sup> in 10<sup>4</sup> s)</u>	<u>5AU (2m)</u>	<u>1 AU (4m)</u>
– Earth at 10 pc	2.5E+03	1.0E+04
– Exo-zodi	2.6E+05	1.0E+06
– <i>Local Zodi</i>	<i>1.7E+04</i>	<i>1.9E+06</i>
– Nulled Star	1.2E+04	4.7E+04
– Dark Current	5.0E+04	5.0E+04
– Total Counts	3.4E+05	3.0E+06
– Noise ( counts)	582	1746
<hr/>		
<b>SNR</b>	<b>4.3</b>	<b>5.7</b>



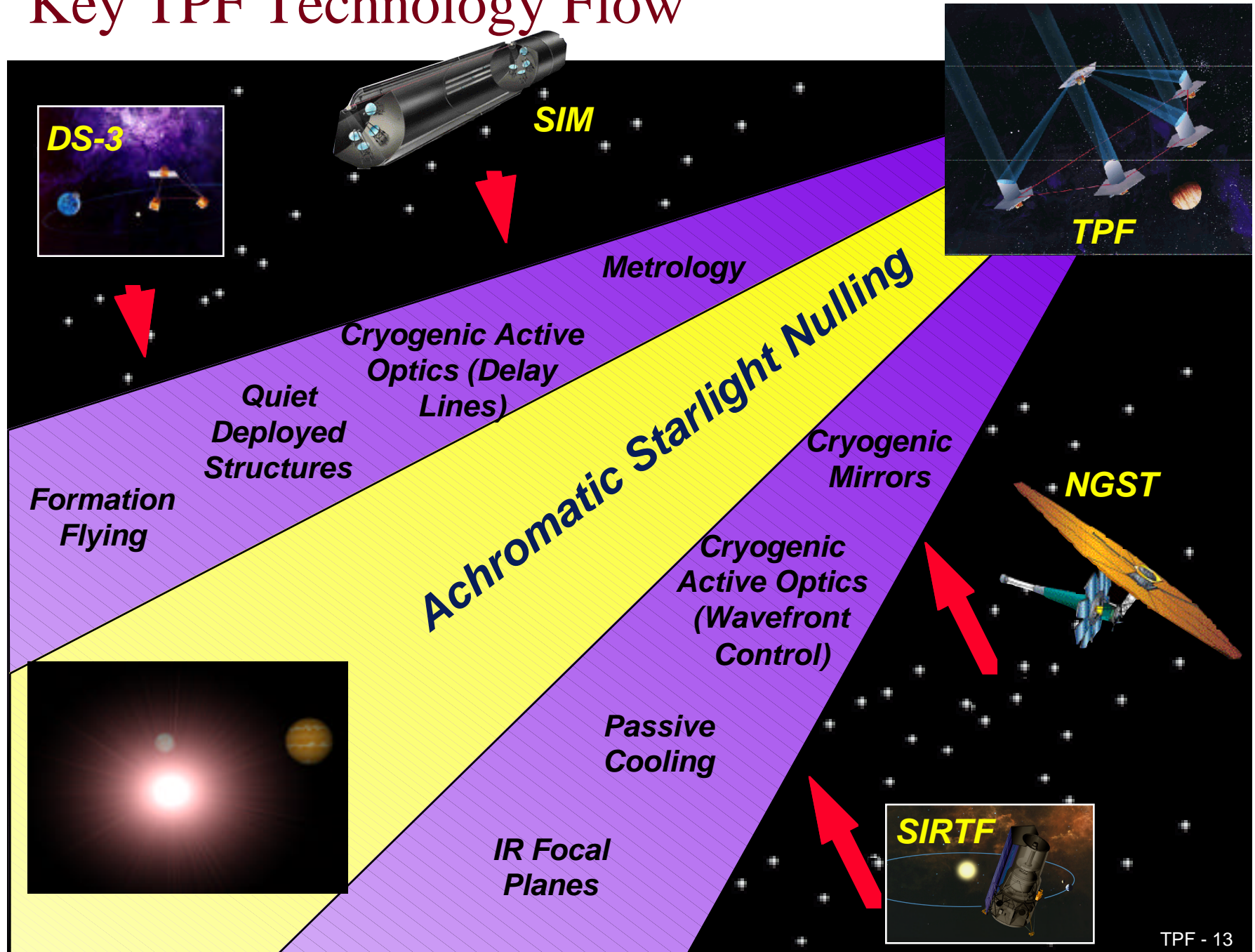
# Monolith Configuration



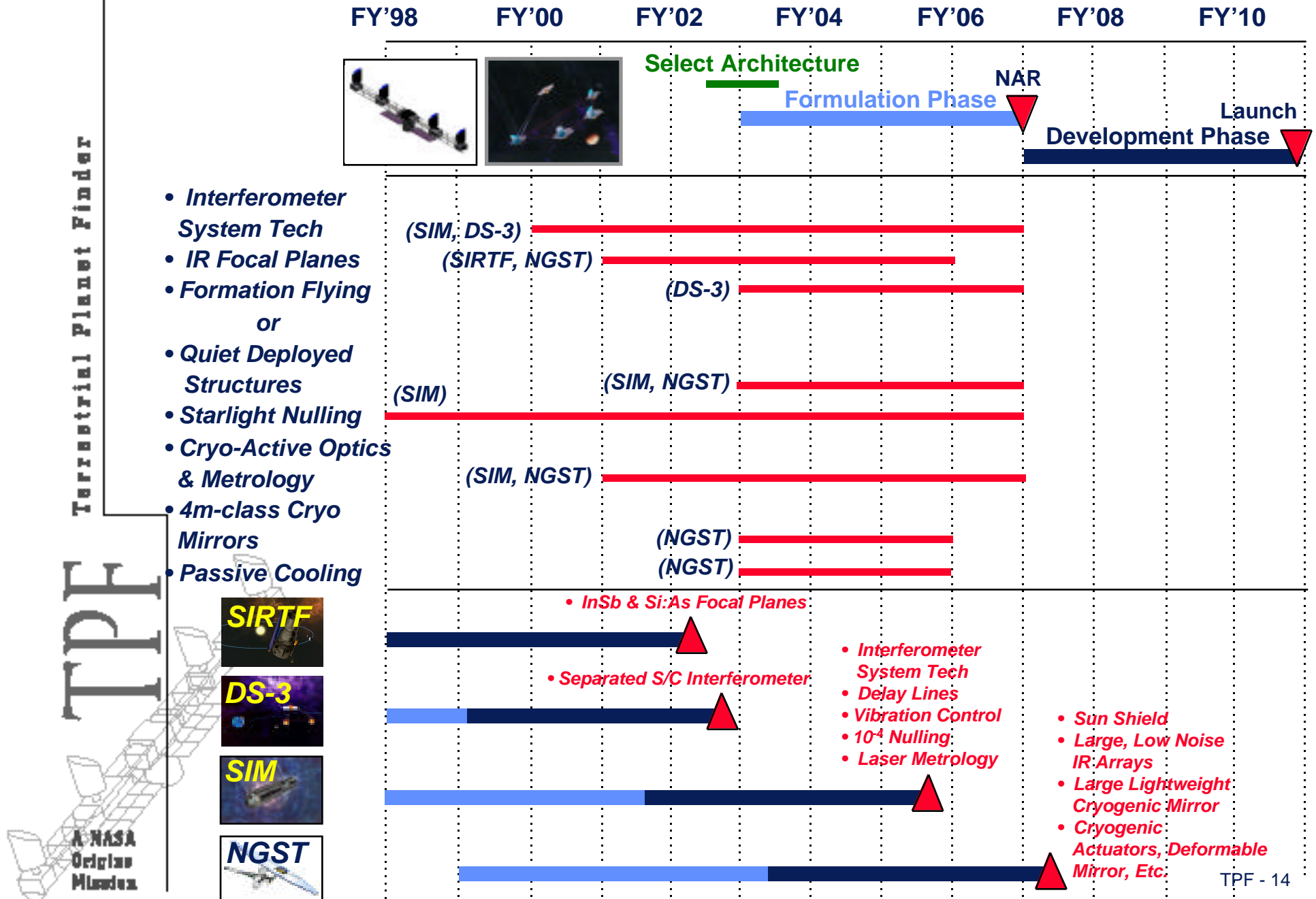
# Free-Flyer Configuration



# Key TPF Technology Flow

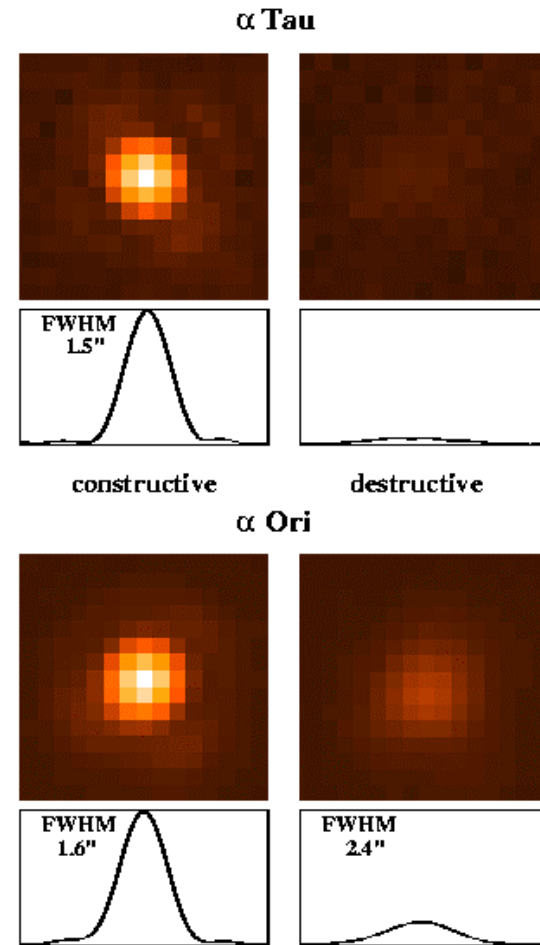


# TPF Technology Development



# Nulling Technology Critical to TPF

- UofA pursuing cryogenic nulling technology in laboratory and at telescope for both TPF and SIM
  - Demonstrated 20:1 broadband null at MMT at  $10\ \mu\text{m}$
  - 3-year program for technology and instrument concepts
- JPL pursuing nulling for SIM in visible
  - Demonstrated 20:1 null at  $0.5\ \mu\text{m}$



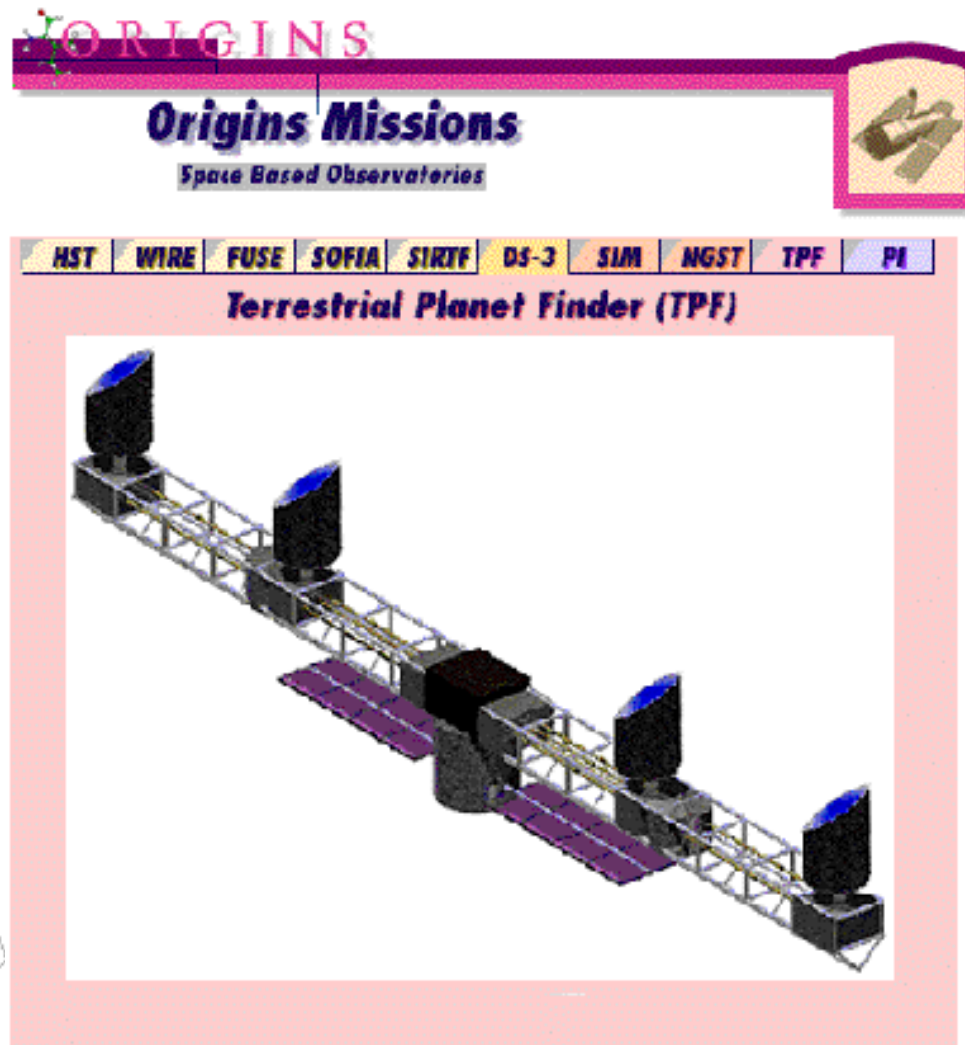
UofA results from MMT



# Plans for 1998

- Need to accelerate development of interferometric nulling technology
  - In context of TPF Technology Roadmap
- Need to prepare advocacy for Decade Review
- Need to pursue TPF designs with enough fidelity to identify technology issues
- Coordinate with other centers on TPF
  - Astrobiology with Ames
  - Large apertures with GSFC
- Current funding level (\$400 k) inadequate to support continued progress in science and technology of TPF
  - Need to maintain industrial interest in interferometry and large apertures via small studies that relate TPF problems to SIM & NGST
  - Request \$1M for FY 99





For more information about the Terrestrial Planet Finder (TPF) Mission, check out our website:

<http://origins/missions/tpf.html>